Soil-based interventions for economic returns in India

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Available empirical evidence for the association between soil-based interventions and economic returns in India reveals the following. First, integrated nutrient management (INM) is superior to balanced nutrient management (BNM) in terms of yield and economic profit for the cultivation of maize and soybean. Second, incentivizing the usage of INM rather than BNM is likely to provide a better yield and higher income to rice, wheat and potato farmers. Third, more studies on various crops are required to scientifically compare and reach a definite conclusion on the yield and economic returns from different types of fertilizer applications – INM, BNM and organic or biofertilizers. These findings have policy implications in India since the Soil Health Card scheme was centralized in 2015.

Keywords: Community-based farming, crop yield, economic returns, fertilizers, soil interventions.

ADOPTION of exploitative agriculture or intensive inorganic farming system during as well as post-green revolution era led to a significant rise in crop yield in the ensuing years, but the growth began to taper off in the following decades[1–3]. A serious re-examination indicated that, apart from other factors, an imbalanced usage of chemical fertilizers was one of the major contributors[3]. It also emerged that although fertilizer consumption was increasing, the output elasticity per unit use of chemical fertilizer was falling[4]. This was attributed primarily to the massive fertilizer subsidy given to nitrogen-based urea fertilizer since 1977 (ref. 5). Nevertheless, there was some concern about deteriorating soil health. Various studies have examined issues related to soil health, use of fertilizers and subsidies, crop yield and economic returns[6–11]. Lal pointed to the rapid deterioration of India's soil due to the almost complete abandonment of the organic farming system, which was in vogue in most parts of the country until the 1950s. Likewise, Swaminathan[2] has been actively advocating for an evergreen revolution through sustainable agricultural practices or integrated farm management, a healthy amalgam of inorganic and organic farming systems. The present study, therefore, aims to review the relationship between soil-based interventions, crop yield and economic returns (in terms of benefit–cost ratio, hereafter BCR) in India.

Policymakers recognized the ill-effects of imbalanced and indiscriminate usage of chemical fertilizers in 2009. So in 2010, a new nutrient-based subsidy (NBS) scheme for fertilizer was implemented[12]. NBS implicitly encourages farmers to get their soils tested and apply fertilizers accordingly. In this context, the necessity of a Soil Health Card (SHC) for each farmer has emerged[13]. It became particularly relevant with the centralization of the SHC scheme in 2015. In the last two decades, this scheme has mainly been promoted by both National and State Governments. The general thrust of the SHC scheme remains primarily on recommendations regarding chemical fertilizers[11] and curtailing subsidies on these fertilizers[10]. Therefore, in this study we analyse which fertilizer application is the most suitable in terms of crop yield and economic benefits. It will help analyse the trade-off between soil health and economic benefits to arrive at an optimum recommendation. Specifically, it gears towards providing a recommendation for better usage of SHC from an economic perspective. More generally, this analysis will help draw inferences for economic policy purposes using the evidence from laboratory experiments and field trials regarding several fertilizer applications. To the best of our knowledge, only one study has compared integrated nutrient management (INM) with regular practices[14].

Data and methods

Following Bahinipati *et al.*[15] and Bahinipati and Patnaik[16], this study has adopted the PRISMA method for review.

Search strategy

We have focused on three sources for the collection of journal articles. These are Web of Science, Scopus and JSTOR. Phrases identified from preliminary readings and keywords from the phrases have been retained for searching the literature. For example, from phrases 'organic farming', 'soil moisture retention' and 'integrated pest management', keywords like 'organic', 'moisture' and 'pest' were selected and used to construct the strings (Table 1). As a second step, three types of strings were constructed based on these

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keywords. The first string was to identify as many journal articles as possible about soil health published between 1999 and 2019 in India that included economic outcomes captured through crop yield or crop productivity. The second string was meant to select published articles only on SHC schemes in India containing economic outcomes. The final string attempted to search for articles related to India on different aspects of soil health (Table 2).

Inclusion and exclusion criteria and selection process

The total number of papers from all the sources was 3725. The duplicated articles from the above two sources, amounting to 616, were dropped. These articles went through the first-stage screening based on topic, abstract and keywords, and the second-stage screening based on content in the introduction and conclusion. Table 3 presents the exclusion and inclusion criteria. Figure 1 depicts the flow chart of the search, selection and screening of articles followed to arrive at the final list of papers. Following the systematic process, we selected 16 articles. We did an additional search in specific journals like *Economic and Political Weekly* and the *Indian Journal of Agricultural Economics*, and browsed references of the selected articles. In doing so, we have appended six additional articles. The final review consisted of a set of 22 papers.

Results and discussion

The review examined crop productivity denoted by yield in tonnes per hectare and economic returns in terms of BCR. It emerges from the selected studies that all except one derive their results from experiments conducted over a short period, ranging from one to nine years. Only one paper presents results based on an experiment spread over 31 years, i.e. Mishra *et al.*[17]. Table 4 reports findings of cropwise yield and BCR for each treatment. The comparison of yield or BCR across studies needs to be clarified. The yield can vary considerably across studies because of soil quality, soil fertility and water management in different study areas for the same crop, even with similar treatment. These variations could also be because of different applications of various fertilizers – N, P and K organic or bio-fertilizers – but given the variations in other factors, it is outside the scope of this study to segregate the impact of variations in fertilizer usage from the variation in other factors. Hence, the results for the same crop in the same experiment from different treatments – T1 (balanced nutrient management (BNM) or recommended dose of chemical fertilizer (RDF)), T2 (integrated nutrient management (INM) or integrated plant nutrient supply (INPS)) and T3 (organic fertilizer (OF) or biofertilizer (BF)) – have been compared to draw meaningful inferences.

Table 4 suggests that barring a few exceptions, any treatment – T1, T2 and T3 – seems to provide a better result than control in terms of yield and economic returns. So any scientifically informed treatment is better than no treatment or traditional farmer's practices. However, some studies conducted with T1, T2 and T3 indicate that, in most cases, T3 provides a lower yield and BCR than T1 and T2. Since studies with T3 treatment are sparse, we restrict the analysis to comparing the results between T1 and T2 for crops in which results from at least two experiments are available. Therefore, this analysis will not draw any conclusion even for crops like groundnut, which multiple studies have analysed, but there is only one experiment which contains both T1 and T2 treatments.

Specifically, this study will analyse the results of the following crops – rice, wheat, maize, soybean, onion and

Table 1. Keywords or phrases used for the inclusion of research paper

Key concept	Key terms
India	India
Agriculture	Crop productivity, crop yield
Soil health	Soil health, soil health card
Soil properties	Moisture, saline, alkali, acid, fertility, carbon
Soil mapping	Survey, sensing
Intervention	Pest, nutrient, organic, manure, fertiliser, fertilizer, legume, system

Table 2. Strings used for searching articles

((((India) AND (crop productivity OR crop yield)) AND (soil health))
((((India) AND (crop productivity OR crop yield)) AND (soil health card))
((((India) AND (crop productivity OR crop yield)) AND (soil health card)) AND (pest OR nutrient OR organic OR manure OR fertiliser OR fertilizer OR moisture OR saline OR alkali OR acid OR survey OR fertility OR carbon OR legume OR sensing or system))

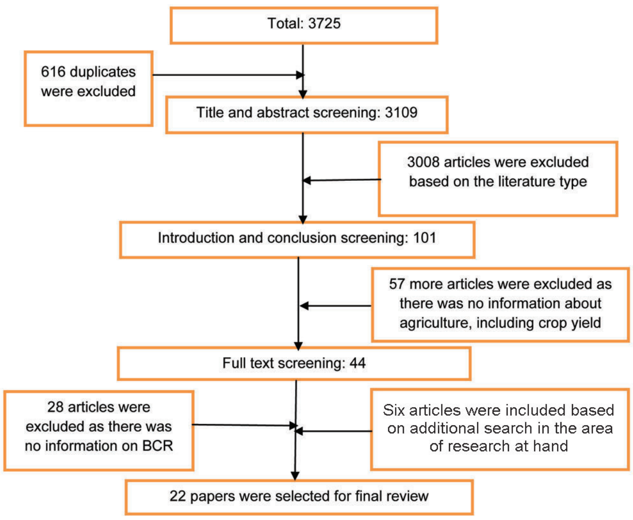

Figure 1. Flow chart of search, selection and screening of articles.

Table 3. Exclusion and inclusion (eligibility) criteria adopted for screening articles

Criterion	Eligibility	Exclusion
Literature type	Journals (only empirical papers)	Others
Language	English	Non-English
Time period	Simple pooled data analysis	If the article was published before 2010
Country	India	Non-India
Title and abstract	Focuses on soil health and crop yield and/or economic returns	If the article did not aim to analyse the relationship among soil health, yield and economic returns
Full-article screening	Empirical information on soil based interventions, yield and economic returns in terms of benefit–cost ratio	If the article did not have any empirical analysis on soil-based interventions, yield and economic returns

potato – for which results for T1 and T2 from at least two experiments are available. However, it is worth noting from Table 4 that for all other crops with only results of one experiment for T1 and T2, the yield is generally higher from T2 compared to T1. Further, for all crops, except ashwagandha, BCR is also higher from T2 compared to T1. So there seems to be an indication that treatment T2 is more effective than T1. Hence, more studies must be conducted with treatment T1 and T2 on various crops to arrive at a definite conclusion regarding the efficacy of different fertilizer usage from the perspective of yield and economic returns.

Considering both economic returns and crop yield, we find that only in the case of maize and soybean there are higher economic returns and higher yield from T2 compared to T1. Dey[18] reported a 9.23–10.59 tonnes/ha yield and BCR of 2.05–2.14 from T2, which was higher compared to 8.97–10.33 tonnes/ha yield and BCR of 2.05–2.14 from T1 for maize. Chander *et al.*[6] observed that in the case of maize, the yield (2.53–3.62 tonnes/ha) and BCR (4.59–8.24) from T2 were higher than the yield (2.18–3.39 tonnes/ha) and BCR (1.59–4.28) from T1. In the case of soybeans, Chander *et al.*[6] provided the result of two different experiments. Experiment 1 revealed that yield (1.46–2.31 tonnes/ha) and BCR (3.4–10.2) from T2 were higher than the yield (1.38–2.12 tonnes/ha) and BCR (1.31–2.99) from T1. Experiment 2 also revealed that the yield of soybean (2.02–2.62 tonnes/ha) from T2 was higher than that (1.81–2.37 tonnes/ha) from T1. Likewise, BCR from T2 (3.61–8.42) was also much higher than that from T1 (0.85–3.32). Dwivedi *et al.*[19] reported soybean yield (1.83 tonnes/ha) and BCR (4.05) from T2 to be higher than the yield (1.18 tonnes/ha) and BCR (2.88) from T1. Thus, in the case of maize and soybean, T2 performs better than T1 with respect to economic returns and yield.

For onion, Dey[18] reported a higher yield (17.72–19.48 tonnes/ha) for T2 compared to T1 (17.24–18.75 tonnes/ha). However, Dhillon and Singh[20] reported a lower yield (20.63–40.70 tonnes/ha) for T2 compared to T1 (42.12 tonnes/ha). In terms of economic returns, Dey[18] and Dhillon and Singh[20] observed BCR from T2 to be lower than that from T1. BCR was 1.10–2.41 from T2 compared to 2.63 from T1, according to Dhillon and Singh[20]. According to Dey[18], it was 2.33–2.50 from T2 compared to 2.34–2.50 from T1. In the case of rice, wheat and potato, the yield was generally higher from T2 compared to T1. However, this cannot be unambiguously inferred as far as economic returns are concerned. The rice yield from two experiments by Dey[18] was 7.11 tonnes/ha from T2 compared to 6.01–6.94 tonnes/ha from T1 in experiment 1, and 6.94–8.34 tonnes/ha from T2 compared to 6.68–8.18 tonnes/ha from T1 in experiment 2. Similarly, in the case of rice, Mishra *et al.*[17] reported that, on average, the yield of 8.11–9.07 tonnes/ha from T2 is higher compared to 6.39–8.48 tonnes/ha from T1. Patra *et al.*[21] also observed that the yield from T2 (4.17–4.41 tonnes/ha) was higher than that from T1 (4.18 tonnes/ha). However, according to Dey[18], BCR for rice in experiment 1 from T2 (1.75) was higher compared to T1 (1.52–1.74) but this was not the case in experiment 2, with T2 and T1 values of BCR at 1.97–2.16 and 1.92–2.18 respectively. Further, BCR for rice from T2 (2.12–2.42) was higher than T1 (1.91–2.39), according to Mishra *et al.*[17], but BCR for rice from T2 (1.64–1.66) was lower than T1 (1.72) according to Patra *et al.*[21]. A similar picture emerges for wheat and potato. Yield for wheat in all four experiments – Devi *et al.*[22], Desai *et al.*[23], Chander *et al.*[8], Dey[18] – was higher from T2 compared to T1. However, BCR for wheat in all experiments, barring Devi *et al.*[22], was lower from T2 compared to T1. In the case of potatoes the yield from T2 in Dey[18] and Patra *et al.*[21] was higher than T1, but BCR for potatoes from T2 was higher in Dey[18] and lower in Patra *et al.*[21] compared to T1.

It is clear from the above analysis that for maize and soybean, INM is better than BNM in terms of yield and economic returns. It is worth mentioning here that maize and soybean have become essential crops in India. Maize alone contributes 9% of the total food grain production (https://farmer.gov.in/imagedefault/pestanddiseasescrops/KHARIF-2012.pdf). Though the production of maize has increased from 1.73 million MT in 1950–51 to 27.8 million MT in 2018–19, the yield is still less than 3 tonnes per ha, which is half the world average. This is why India is ranked fourth in the world in maize cultivation area but seventh in production (https://iimr.icar.gov.in/india-maze-scenario/). Maize is also cultivated for conversion to ethanol for fuel usage (https://www.thehindubusinessline.com/economy/agri-business/to-produce-ethanol-india-will-use-corn-as-feedstock/article34824036.ece). India ranked fifth in the area and production of soybean after the US, Brazil,

Table 4. Crop yield and BCR under each treatment (fertilizer usage) for different crops

Author (year)	Crop yield ('000 kg per ha)				Economic returns (BCR)			
	C	T1	T2	T3	C	T1	T2	T3
Rice								
Dey (ref. 18)[i]	–	6.01–6.94	7.11	–	–	1.52–1.74	1.75	–
Dey (ref. 18)[ii]	–	6.68–8.18	6.94–8.34	–	–	1.92–2.18	1.97–2.16	–
Chouhan *et al.*[33]	5.09	6.08	–	–	1.5	1.7	–	–
Mishra *et al.*[17]	4.03–8.51	6.39–8.48	8.11–9.07	–	1.26–1.85	1.91–2.39	2.12–2.42	–
Bhat *et al.*[34]	4.26	–	7.10–8.06	–	2.58	1.12–3.79	–	–
Patra *et al.*[21]	–	4.18	4.17–4.41	4.10–4.62	–	1.72	1.64–1.66	1.34–1.60
Chander *et al.*[8]	3.98–4.65	4.95–5.80	–	–	–	8.48–10.6	–	–
Maize								
Dey (ref. 18)[iii]	–	8.97–10.33	9.23–10.59	–	–	2.04–2.13	2.05–2.14	–
Chouhan *et al.*[33]	1.56	2.30	–	–	1.4	1.9	–	–
Chander *et al.*[8]	3.93–5.42	5.16–7.80	–	–	–	8.81–15.6	–	–
Chander *et al.*[6]	1.56–2.85	2.18–3.39	2.53–3.62	–	–	1.59–4.28	4.59–8.24	–
Chander *et al.*[7]	5.54–5.81	6.55–7.32	–	–	–	3.7–8.8	–	–
Choudhury *et al.*[35]	1.90	–	–	3.20–4.35	1.30	–	–	1.29–1.98
Wheat								
Dey (ref. 18)[iv]	–	3.55–4.07	3.63–4.16	–	–	1.54–1.66	1.49–1.62	–
Dey (ref. 18)[v]	–	2.90–3.93	2.98–4.05	–	–	1.33–1.66	1.31–1.61	–
Chander *et al.*[8]	1.05	1.46	–	–	–	3.18	–	–
Devi *et al.*[22]	1.68–1.69	3.49–3.83	3.38–5.01	3.13–3.38	1.2–1.21	2.37–2.70	2.15–2.74	1.25–1.33
Desai *et al.*[23]	–	3.21–3.42	3.51–4.22	–	–	2.71–2.75	2.38–2.63	–
Soybean								
Chouhan *et al.*[33]	1.43	1.63	–	–	1.6	2	–	–
Chander *et al.* (ref. 6)[vi]	1.19–1.90	1.38–2.12	1.46–2.31	–	–	1.31–2.99	3.4–10.2	–
Chander *et al.* (ref. 6)[vi]	1.70–1.94	1.81–2.37	2.02–2.62	–	–	0.85–3.32	3.61–8.42	–
Chander *et al.*[8]	1.06–1.94	1.41–2.61	–	–	–	4.51–11.9	–	–
Dwivedi *et al.*[19]	–	1.18	1.83	–	–	2.88	4.05	–
Groundnut								
Chander *et al.*[6]	0,82–1.34	0.96–1.53	1.06–1.66	–	–	1.78–2.42	5.84–7.79	–
Chander *et al.*[36]	1.00–1.20	1.28–1.57	–	–	–	6.24–8.24	–	–
Chander *et al.*[8]	1.08–1.48	1.44–2.06	–	–	–	8.13–12.0	–	–
Chander *et al.* (ref. 7)[vi]	0.33–1.40	0.50–1.78	–	–	–	1.6–8.2	–	–
Chander *et al.* (ref. 7)[vi]	0.48–1.82	0.75–2.97	–	–	–	3.5–15.2	–	–
Sorghum								
Chander *et al.* (ref. 8)[vi]	1.71–2.70	2.31–2.74	–	–	–	4.93–7.21	–	–
Chander *et al.* (ref. 8)[vi]	1.18–1.51	1.70–2.04	–	–	–	3.05–4.98	–	–
Chander *et al.*[7]	2,27	2.27	–	–	–	3.5	–	–
Cotton								
Dey (ref. 18)[vii]	–	2.67–3.07	2.84–3.24	–	–	1.46–1.64	1.51–1.68	–
Deva *et al.*[37]	0.69–1.15	0.82–1.45	–	–	0.5–0.70	0.63–0.81	–	–
Chander *et al.*[7]	1.06–2.47	1.35–4.01	–	–	–	3.7–28.5	–	–
Pearl millet								
Chander *et al.*[6]	1.34–2.21	1.47–2.56	1.61–2.80		–	0.81 to 1.43	2.26 to 3.66	–
Chander *et al.*[8]	1.24–1.66	1.72–2.51	–	–	–	3.40–4.91	–	–
Banana								
Mayadevi *et al.* (ref. 38)[viii]	4.25	–	10.81	6.73–7.24	–	–	1.11	1.01–1.26
Bindu[39]	1.48	1.83–2.06			1.4	1.71–1.94		
Onion								
Dhillon and Singh (ref. 20)[ix]	16.32	42.12	20.63–40.70	–	0.49	2.63	1.10–2.41	–
Dey[18]	–	17.24–18.75	17.72–19.48	–	–	2.34–2.50	2.33–2.50	–
Chickpea								
Chander *et al.*[7]	0.61–2.13	1.20–2.95	–	–	–	6.0–8.4	–	–
Chander *et al.*[8]	0.74–1.40	0.91–1.84	–	–	–	2.80–7.22	–	–
Sunflower								
Chander *et al.*[7]	0.36–1.59	0.58–2.02	–	–	–	2.6–5.0	–	–
Chander *et al.*[8]	0.80–1.31	1.04–1.83	–	–	–	3.84–7.97[x]	–	–
Potato								
Dey[18]	–	27.60–38.80	29.20–40.40	–	–	1.85–2.38	1.94–2.46	–
Patra *et al.*[21]	–	1.17	1.17–1.19	1.08–1.23	–	1.72	1.64–1.66	1.34–1.60

(*Contd*)

Table 4. (*Contd*)

Author (year)	Crop yield ('000 kg per ha)				Economic returns (BCR)			
	C	T1	T2	T3	C	T1	T2	T3
Apple								
Banyal and Banyal[40]	7.11	7.86–8.72	–	–	2.45	2.48–2.80	–	–
Ashwagandha								
Dey[18]	–	0.67–0.87	0.70–0.91	–	–	1.31–1.24	1.28–1.19	–
Beetroot								
Dey[18]	–	39.50–49.98	40.48–51.37	–	–	2.37–2.77	2.37–2.78	–
Brinjal hybrid								
Kirankumar *et al.*[41]	18.24–45.83	42.39–58.12	51.66–59.91	–	1.29–3.04	2.84–3.86	3.45–3.94	–
Cabbage								
Dey[18]	–	59.90–70.50	61.00–71.80	–	–	2.43.2.78	2.44–2.79	–
Carrot								
Dey[18]	–	40.90–59.90	43.30–62.60	–	–	2.45–3.07	2.54–3.15	–
Castor								
Chander *et al.*[7]	0.70	0.83	–	–	–	3.9	–	–
Cowpea								
Chander *et al.*[7]	1.22–1.42	–	–	–	–	1.9	–	–
Dwarf field pea								
Mishra *et al.*[44]	2.09–2.12	2.44–2.73	–	2.42–2.76	1.78–1.86	2.04–2.17	–	1.93–2.27
Finger millet								
Chander *et al.*[8]	1.33–1.75	1.76–2.50	–	–	–	3.80–5.44	–	–
Foxtail millet								
Chander *et al.*[36]	0.70	0.93	–	–	–	3.13	–	–
Gram								
Dey[18]	0.93	1.30–1.65	1.93	–	1.47	2.32–3.16	3.34	
Green gram								
Chander *et al.*[7]	0.20	0.30	–	–	–	3.6	–	–
Kodo millet								
Dwivedi *et al.*[42]	0.62	1.12–1.44	1.20–1.59	0.67–0.82	1.09	1.65–1.86	1.62–1.90	1.10–1.18
Pigeonpea								
Chander *et al.*[8]	0.54–1.23	0.73–1.65	–	–	–	4.39–9.09	–	–
Radish								
Dey[18]	–	37.20–48.80	38.40–50.60	–		2.23–2.74	2.24–2.78	
Sugarcane								
Chander *et al.*[8]	114.73–136.56	131.45–151.36	–	–	–	–	–	–
Tomato								
Dey[18]	–	70.90–88.30	72.20–89.50	–	–	2.47–2.86	2.50–2.88	–

Note: Control (C), Farmers' practice or C; T1, BNM or RDF; T2, INM or INPS; T3, OF or BF; –, The particular treatment has not been considered in this study; (i), Flooded; (ii), SRI method (the system of rice intensification); (iii), Hybrid; (iv), Hill area; (v), Plain; (vi), Different seasons; (vii), *Bt*-cotton; (viii), Kilograms per plant; (ix), Bulb yield; (x), Information given only for rainy season.

Argentina and China. However, the productivity of soybean in the country is around 1.1 tonnes/ha, which is half of the average world productivity of 1.1 tonnes/ha (ref. 24). Since INM has advantages of both yield and economic returns over BNM, the promotion of INM in maize and soybean will increase not only the yield but also the revenue of the farmers since many farmers in India are involved in the production of these crops.

For rice, wheat and potato, INM is better than BNM in terms of yield, but it needs clarification as to which one is better in terms of economic returns. Hence, financially incentivizing the usage of INM – a combination of organic or bio-fertilizers, chemical fertilizers and micronutrients – may help promote not only better yield but also higher income among rice, wheat and potato farmers. In 2020–21, rice and wheat covered 35.3% and 24% respectively, of the gross cropped area under foodgrain cultivation. They contributed 40% and 35.3% respectively, of gross foodgrain production in the country (https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%2-0-%202021%20(English%20version).pdf). They also contributed immensely to domestic and export markets. Potato production was 56.17 million tonnes in 2020–21, which is 28% of gross vegetable production covering an area of 2.2 million hectares (20% of the gross cropped area under vegetables) (https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/jul/doc202271470601.pdf, and https://pib.gov.in/PressReleasePage.aspx?PRID=1841480). Hence, this study suggests that it may make sense from a productivity and economics returns point of view to consider incentivizing the usage of INM rather than BNM for rice, wheat and potato cultivations.

As the above analysis shows, in the case of many other crops, the INM provides better results than BNM in crop yield and economic returns. However, this needs to be studied extensively through more experiments to reach a definite conclusion. Ramesh *et al.*[25] suggest more research with experiments and rigorous comparative analysis of BCR and yield from T1, T2 and T3. Using different combinations of chemical fertilizers with organic (or bio) fertilizers is essential to evolve a better long-term agricultural strategy from the perspective of both soil health and economic returns.

In India, using only organic fertilizers like cow manure and BF producers like earthworms through organic practices like zero-budget natural farming[26] seemed to gain some traction in a few states like Maharashtra, Andhra Pradesh and Karnataka. However, Prasad[27] points towards various practical problems with organic farming, apart from being expensive for a farmer to adopt and its lack of availability[28]. Only an INM approach with a balanced dose of chemical fertilizer and organic manures would help improve soil health from an ecological perspective. Following Lal[29], this can be termed as the integration of physical, chemical and biological measures of soil health. For example, a cropping system that uses sufficient organic nutrients registers an increase in soil organic carbon by 10–20% (ref. 30). Moreover, Lal[29] has emphasized the necessity to increase organic carbon, along with the usage of chemical fertilizer, through the usage of organic manure like crop residue to improve soil health. Instead of burning, if crop residue gets added to the soil[31] in regions of intensive agriculture then it would provide much needed food for microbes, i.e., soil organic carbon (SOC) and increase the crop yield[43]. The simple pooled data analysis in this paper also shows the same.

Conclusion and policy recommendations

This paper aims to review the relationship between fertilizer-based soil interventions, yield and economic returns. In doing so, we have selected 22 papers by following the PRISMA approach. In conclusion, it can be said that this review has provided valuable insights for appreciating the efficacy of INM over BNM as far as maize and soybean are concerned. The productivity and economic returns of maize and soybean farmers will increase more with the adoption of INM than BNM. Therefore, from the policy point of view, it may make sense for the government to promote INM rather than BNM as far as the cultivation of maize and soybean is concerned. Agricultural schemes promoting the cultivation of maize and soybean through INM rather than BNM would benefit. Secondly, concerning rice, wheat and potato farmers, it may help to evolve an incentive mechanism, which will help to promote the adoption of INM than BNM among farmers. The adoption of INM will not only provide a higher yield of rice, wheat and potato but incentivizing the usage of INM may also help to make it lucrative for the farmers.

This requires redesigning the SHC to include not only recommendations regarding balanced usage of chemical fertilizers and micronutrients but also organic and bio-fertilizers. The results obtained through soil tests should provide not only information on chemical but also physical and biological properties of the soil with appropriate recommendations from the perspective of INM. This would require the enhancement of soil testing and soil mapping facilities in the country to cover as many farmers as possible. The site-specific nutrient management soil tests based on SHC containing recommendations for suitable customized fertilizer[32] would improve soil health and increase crop yield. It also requires a paradigmatic shift in policymakers' thinking to focus on INM rather than BNM through proper research and development on these issues. It also requires re-envisioning the SHC scheme in terms of production by masses where traditional ecological knowledge of the community synergizes with the State led modern scientific understanding of soil health.

Further, there needs to be more experiments and studies on other crops involving T1, T2 and T3 treatments to draw factual inferences regarding different types of fertilizer usage from the perspective of yield and economic returns. Any policy decision on this matter requires careful deliberation informed by results from scientific studies. This review is an attempt in that direction. More such studies and reviews are required to reach a definite conclusion on various crops.

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